JPL D-13946

LightSAR
Reference Mission

March 1998

Jet Propulsion Laboratory
California Institute of Technology

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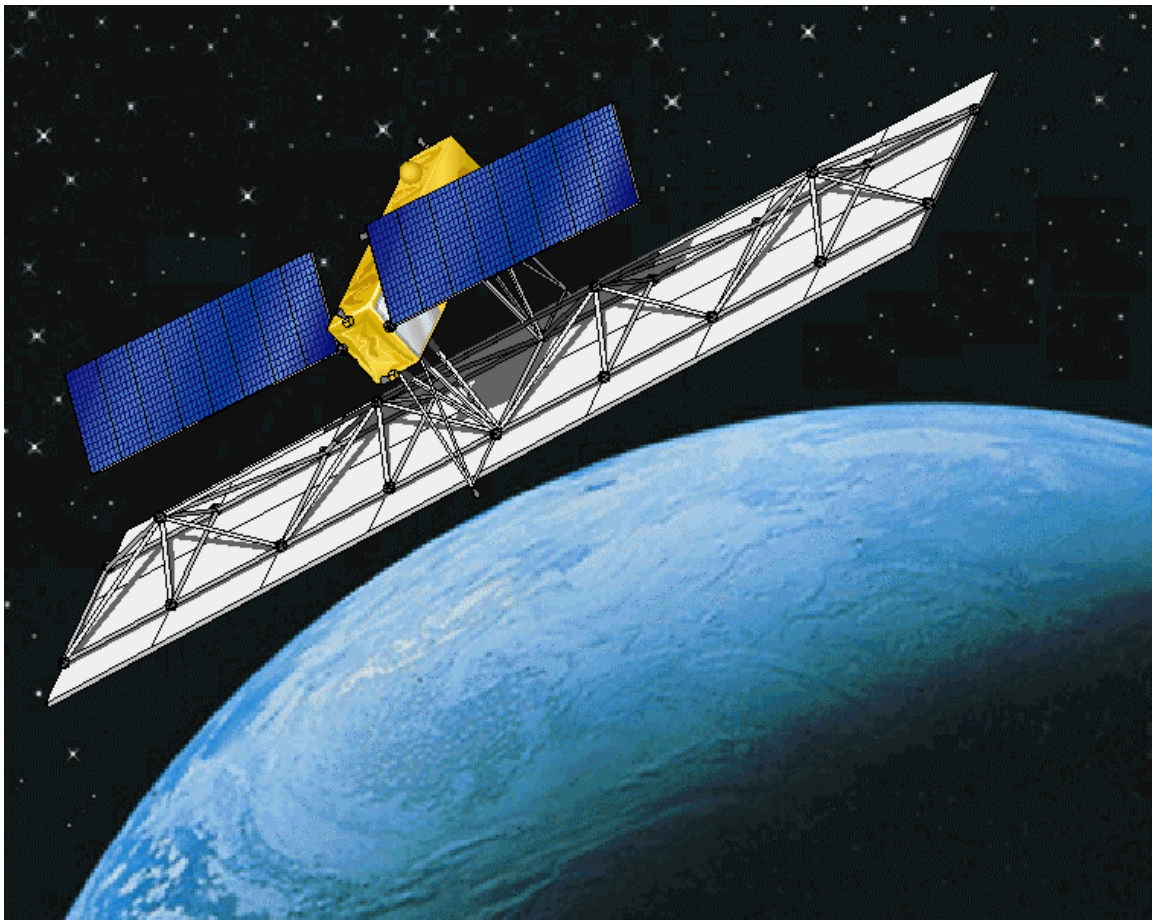

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LightSAR Reference Mission

I. SCOPE

This document describes the essential technical characteristics of a LightSAR mission. The user framework and core payload defined in this document respond to the identified LightSAR science requirements and to an assumed minimum set of LightSAR commercial requirements. The core payload is a single-frequency, L-band, 3-meter-resolution, synthetic aperture radar (SAR), that is very similar to what was called the LightSAR Point Design in 1996. Actual commercial requirements and the resulting final payload definition for LightSAR will not be known until an industry partner for LightSAR is selected.

As with previous LightSAR mission description information, a version of this document will appear on the LightSAR web page at *http://southport.jpl.nasa.gov/lightsar/*.

II. LIGHTSAR OVERVIEW

A. Concept

LightSAR is a NASA initiative to develop a low-cost, Earth-imaging radar satellite system that uses advanced technologies and generates valuable data for both scientific and commercial applications.

The LightSAR Reference Mission described herein is the latest update of the LightSAR Point Design, which was presented at the LightSAR Workshop at the EROS Data Center, Sioux Falls, South Dakota, on August 27-29, 1996 and documented in JPL document D-13926, "LightSAR Point Design Facts," dated September 30, 1996.

A slightly updated Point Design fact sheet was provided to the four industry study teams who performed work for JPL on the "LightSAR System Design and Business Development Study" in 1997. In general, these studies validated a commercial interest in LightSAR and suggested that the LightSAR payload should be enhanced with higher-resolution imaging and a second operating frequency.

B. Programmatics

It is NASA's hope to engage U.S. industry in a partnering arrangement to develop and operate LightSAR.

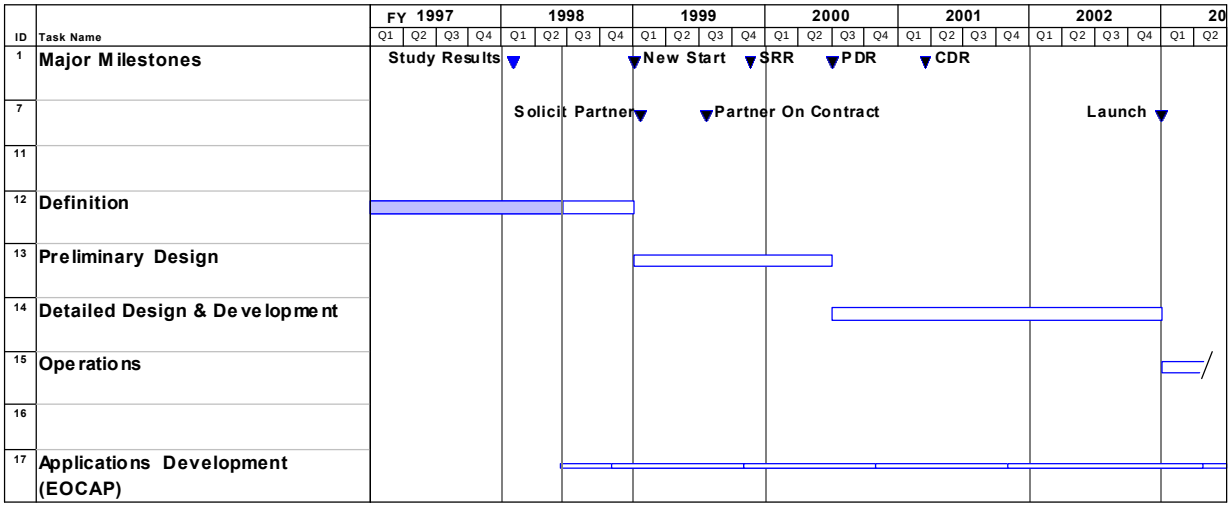
As currently envisioned, NASA's Jet Propulsion Laboratory (JPL) would manage the LightSAR program and lead the L-band radar development. The industry partner would furnish the remaining LightSAR flight and ground system elements and mission operations activities and would provide any additional payload capability that might be required by commercial users. NASA and industry would share the technical and financial risks.

Key Project Milestones:

Project Start	01 Oct 98
Partnership Solicitation Released	15 Oct 98
Partner Selection/On-Contract	31 Mar 99
Launch	30 Sept 02

The project schedule of Table 1 depicts key project milestones and activities.

Table 1. Strawman Project Schedule



III. OBJECTIVES

A. Science Objectives

The LightSAR science objectives are to deliver exciting Earth science data and produce scientific information products that fulfill a fundamental part of NASA's Earth Science Enterprise strategic plan (see JPL D-13945, LightSAR Science Requirements and Mission Enhancements, March 1998). These objectives include:

- Monitoring natural hazards (earthquakes, volcanoes, floods, etc.)
- Measuring glacier/ice sheet mass balance and sea level
- Monitoring the carbon cycle
- Monitoring soil and snow hydrology
- Monitoring the role of the oceans in climate change.

B. Commercial Objectives

LightSAR is a commercial pathfinder mission that will lead the next level of expansion in commercial remote sensing. These objectives include:

- Producing valuable data for a diverse portfolio of commercial applications
- Enabling U.S. industry to open new markets and create long-term businesses that become sustained providers of valuable science and commercial remote sensing data
- Other objectives as determined by industry partner. Industry has the option to add enhanced capability, such as a higher-resolution radar, as an additional payload.

IV. MISSION DESCRIPTION

A. Mission Concept

- Launch: On or about September 30, 2002, by a Taurus XL/Athena II-class vehicle
- Orbit: 600 km, 97.8° inclination, Sun synchronous, 6 a.m. ascending node (97.6 min period; 23 min maximum eclipse)
- Access: Able to image any Earth location every 24 hours (right and left looking)
- Mission lifetime: 5 years continuous operations, including a 90-day checkout period.

B. L-band Science Mission Characteristics

- Global visibility
- Exact repeat orbit in 8-10 days
- Polarimetric measurement mode
- Repeat-pass interferometry measurement mode, with precise orbit control and rapid and accurate orbit knowledge for pointing reconstruction

  Orbit control: Within a 250-m tube
  Orbit knowledge: < 10 cm, available within 3 days of acquisition
  < 100 m, available within 6 hours of acquisition

- Data calibration requirements: Table 2. These values are derived from the accuracies needed by science and commercial retrieval algorithms and calibration techniques.

Resolution: Quad pol. - 25 m
Dual pol. - 25 m
Interferometry - 25 m
ScanSAR - 100 m

- Data processing levels: Table 3. These values are standard data products, from Level 0 raw data to Level 4 processed data.

C. L-band Commercial Mission Characteristics

- High-resolution modes:
  Resolution □ 3 m for 15 x 20-km image spotlight products
  Resolution < 10 m for 22-km stripmap products

- Rapid data take re-tasking

- Site revisits at < 2-day intervals

- Global visibility

- Data processing Levels: (per Table 3)

Table 2. Data Calibration Requirements

	High-Resolution Spotlight	High-Resolution Stripmap	Quad Polarization	Dual Polarization	Repeat-Pass Interferometry	ScanSAR
Absolute (dB):	1	1	1	1	1	1
Long-term Relative (dB):	1.5	1.5	1.5	1.5	1.5	1.5
Short-term Relative (dB):	1	1	1	1	1	1
Channel-to-channel Amplitude (dB)	N/A	N/A	0.5	0.5	N/A	0.5
Channel-to-channel Phase (□)	N/A	N/A	10	10	N/A	10
Interferometric Phase Stability	N/A	N/A	N/A	N/A	10	N/A
Cross-talk (dB)	N/A	N/A	-25	-25	N/A	-25

Table 3. Data Level Definitions

Level	Definition
Level 0	Reconstructed digital video data.
Level 0.5	Level 0 data on low-density computer-compatible media; e.g., Exabyte tape.
Level 1A	Reversibly processed image data (one-look, complex), full-resolution, time-referenced, and annotated with ancillary information; e.g., calibration coefficients and geolocation information.
Level 1B	Level 1A data that has been radiometrically corrected and geometrically resampled; e.g., a SAR image of radar backscatter or an interferogram.
Level 2	Derived geophysical parameters transformed to a uniform map projection or other space-time grid; e.g., ice motion vectors, ice thickness, vegetation index.
Level 3	Level 2 data mapped on uniform space-time grids; e.g., multi-pass mosaics.
Level 4	Numerical model fields derived from Level 1B-Level 3 data, not exclusively using SAR data.

D. Data Collection Strategies

1. Science Data:

Schedule: 7.5 min of L-band SAR data collection per orbit
6 min/orbit @ 105 Mbps in interferometry mode
1.5 min/orbit @ 120 Mbps in quad-pol. mode

1.5 min/orbit @ 60 Mbps average in dual-pol. and scanSAR modes

Latency: Downlink all data taken within 270 min (within next ~3 orbits)

Data return: Minimize data loss due to transmission

2. Commercial Data:

Schedule: Minimum of 3 min of commercial data collection per orbit

Latency: Downlink all data taken within 270 min (within next ~3 orbits)

Data return: Minimize data loss due to transmission

V. FLIGHT SEGMENT

A. L-band SAR Design Characteristics

- Operating frequency: L band @ 1217.5 - 1297.5 MHz

- Operating baselines:
  Moderate-resolution (25 m) L-band SAR for interferometry
  Low-resolution (100 m) L-band SAR for scanSAR
  Multiple polarization settings: HH, HV, VH, and VV

- Electrical power:
  Peak rf power: 8 kW
  Maximum dc power: 600 W
  Keep-alive power: 100 W dc (est.) for radar

- Mechanical:
  Total mass: 250 kg (~225 kg antenna, ~25 kg electronics)
  Antenna deployables: Two 4-panel, fan-folded stacks (reference array design)
  Antenna articulation: None, electronically steerable
  Physical dimensions:
    Stowed SAR antenna: Two panel stacks, 1.35 x 2.9 m x ~15 cm each
    Deployed SAR antenna: 2.9 m (El.) x 10.8 m (Az.)
    Electronics: ~10 x 16 x 30 cm (may be housed in spacecraft bus)

- Thermal: Passive control assumed

- Timing signals: Provided internally in radar system synthesizer module

- Engineering (radar health/welfare) telemetry: 100 kbps (estimated)

- Data acquisition/storage requirements:

Simultaneous record/playback
90 Gbits minimum usable memory, after deducting for formatting and margin

- Operating Modes: (one of the following modes at a time)
  - High-resolution spotlight
  - High-resolution stripmap
  - Quad polarization
  - Dual polarization
  - Repeat-pass interferometry, single polarization
  - ScanSAR
  - (Standby)

These operating modes are depicted in Figure 1 and described in Table 4.

B. Spacecraft (Reference Mission) Design Characteristics

- Pointing:
  - Knowledge: 0.01°
  - Control: Az. = 0.1°, El. = 0.5°
  - Stability: Spotlight mode requirement is TBD

- Slew rate: Maximum 70° roll in ~10 min, including settling (for right & left looking)

- Thermal: Active/passive control

- Navigation:
  - Orbit determination: Via GPS receiver with ground-based post-processing
  - Knowledge (real time): 100 m radial, cross track and along track
  - Knowledge (non-real time): < 10 cm radial and cross track; 1 m along track

- Telecommunications:
  - Downlink:
    - Real-time and playback telemetry data simultaneously
    - Peak data rate: 2 x 150 Mbps @ X band; 200 kbps @ S band
    - Average data rate: Up to four 5-min passes per orbit for X band; one 5-min pass/day for S band
  - Uplink:
    - Peak command rate: 200 kbps @ S band
    - Average command duration: One 5-min pass/day for S band

- Keep-alive power: 300 W dc (estimated)

VI. GROUND SEGMENT

In this reference mission concept the ground segment is primarily the responsibility of the LightSAR industry partner, working with NASA under an agreement in which the LightSAR industry partner:

- Contributes resources and operates the satellite, in return for ultimate effective ownership of the satellite and its data
- Reserves a specified portion of LightSAR operations for NASA science use free-of-charge.

Alternate arrangements will also be considered. For example, the LightSAR industry partner may wish to sell data to NASA, in exchange for a larger up-front investment by industry.

The LightSAR industry partner is presumed to be a business enterprise or consortium of companies that have organized themselves to sell Earth-imaging radar products and services for profit. It is further assumed that the LightSAR industry partner is granted:

- A 15CFR960 remote-sensing operating license by the Department of Commerce
- A license for the LightSAR radar operating frequency band by the NTIA.

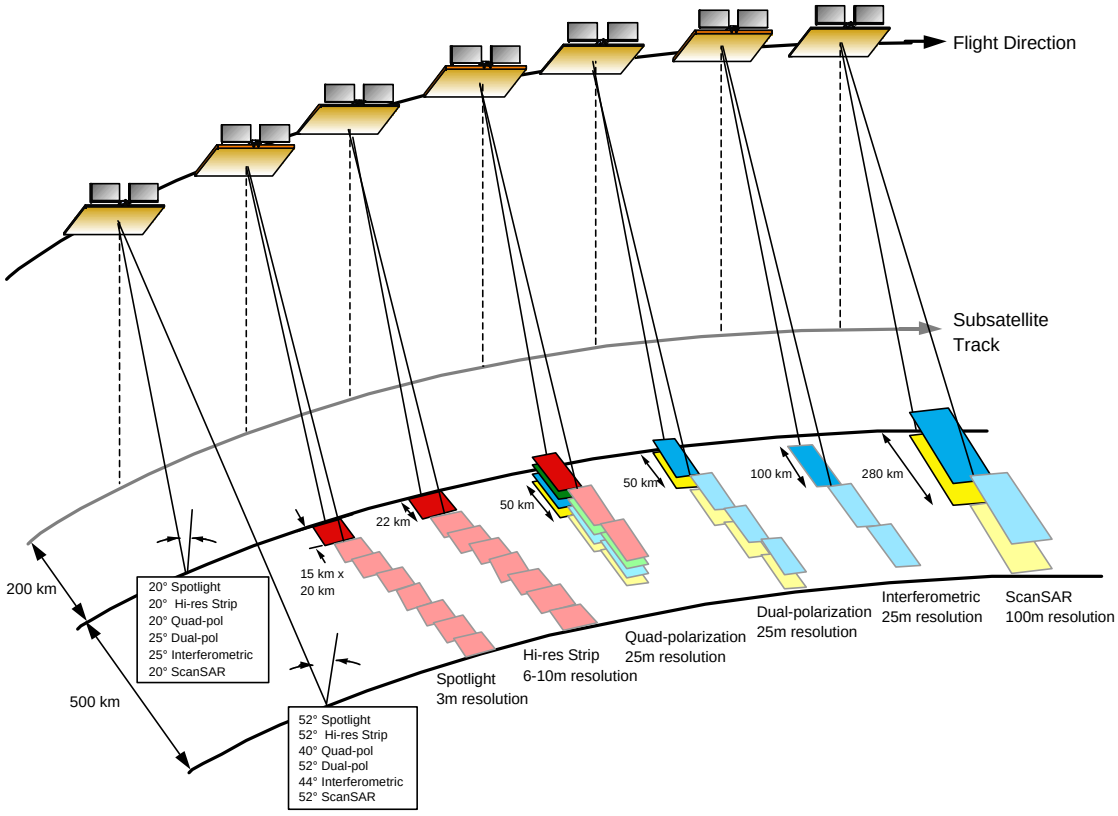


Figure 1. L-band SAR Radar Modes

Table 4. Characteristics of L-band SAR Operating Modes

Mode of Operation	High-Resolution Spotlight	High-Resolution Stripmap	Quad Polarization	Dual Polarization	Repeat-Pass Interferometry	ScanSAR
Resolution (m)	3	6-10	25	25	25	100
Ground Swath (km)	15x20	22	50	50	100	280
Number of Looks	3	3	2	4	4	8
Field of View from Nadir	20-52□	20-52□	20-40□	25-52□	25-44□	20-52□
Polarizations	HH or VV	HH or VV	HH, HV, VV, VH	HH + HV, or VV + VH	HH or VV	HH + HV, or VV + VH
Noise Equivalent □$_0$ (dB)	-20	-20	-30	-30	-30	-25
Bandwidth (MHz)	80	80	10, 15	10, 15	15	2.5
Data Rate (Mbps)	150	150	120	80	60	40

A. Functional Elements

The ground segment design connects the end users to the radar satellite. The functional elements may be implemented in various ways at widely dispersed locations. Actual design implementation will be tailored to the needs of the LightSAR industry partner. Figure 2 shows a simplified conceptual ground segment.

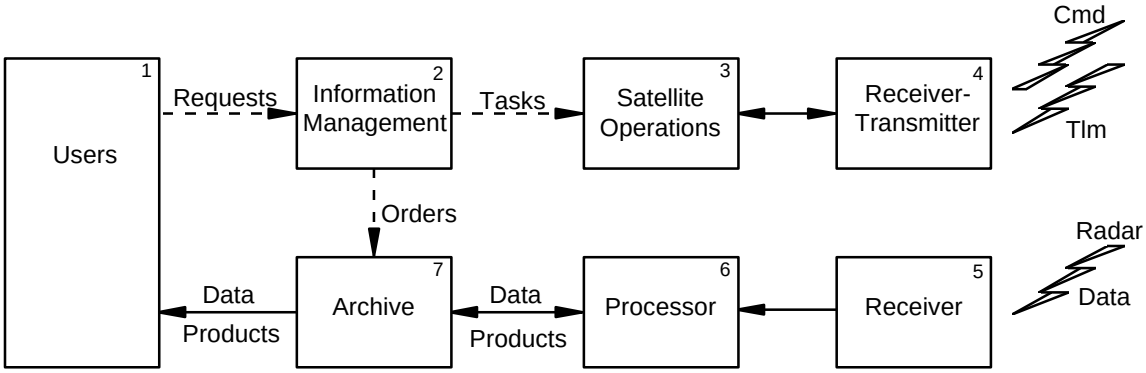


Figure 2. Simplified LightSAR Ground Segment Concept

The Users block represents LightSAR customers, who request products and services, act as data product consumers, and consist of commercial, governmental, and value-added users of LightSAR data.

The Information Management function provides customer services (e.g., sales of data product, software, etc.) and controls radar data flow. It performs data product acquisition planning and prioritization, tasks satellite operations for data acquisition, orders data product from the data archive, manages data product inventory, and manages interfaces with other information and data service centers.

The Satellite Operations function monitors and controls satellite performance in flight and performs radar data acquisition planning, command generation, ground station scheduling, telemetry processing, orbit determination, navigation, station keeping, and resource management.

The telemetry and command Receiver-Transmitter ground station provides the S-band uplink of commands to the satellite and downlink of engineering telemetry transmitted from/to the Satellite Operations element.

The radar data Receiver ground station provides radar data telemetry reception and transport. The X-band downlink data stream is frame synchronized, decoded, and then either (1) packetized or (2) re-transmitted or stored on high-density media for later transport. The ground station reports readiness status to the Satellite Operations element.

The Processor provides processing of incoming and archived radar data to the required level (Table 3), and data product delivery to the archive (Table 5). It also performs data

calibration processing (Table 2) and distributes raw calibration data, as tasked. These services may also be performed by users and/or may be co-located with other functions.

The Archive provides storage and retrieval of data product inventory, media transcription, data product delivery to users, and, in coordination with other information and data service

Table 5. Data Product Design

	High-Resolution Spotlight	High-Resolution Stripmap	Quad Polarization	Dual Polarization	Repeat-Pass Interferometry	ScanSAR
Pixel Spacing (m)	2	4	12.5	12.5	N/A	12.5
Location Accuracy (m)	3	6	100	100	N/A	500
ISLR (dB)	-13	-13	-13	-13	-13	-13
Distortion (%)	0.20	0.20	0.20	0.20	0.20	0.20

centers, the necessary data handling and transport, as ordered by the Information Management element. These services may be co-located with other functions. Planned archive storage lifetime is 10 years.

B. Data/Tasking

The division of responsibilities between the commercial-based LightSAR industry partner and the NASA constituency for the reference mission is summarized as follows:

1. Commercial

   Spacecraft and payload command & control
   Commercial payload calibration
   Commercial payload performance monitoring
   Commercial payload SAR processing
   NASA payload Level 0 processing
   Commercial data archive
   Commercial data management/marketing/sales
   Commercial SAR processor development
   NASA SAR processor development
   Commercial/NASA data acquisition
   NASA payload Level 1 processing

2. NASA/JPL Constituency

   NASA payload calibration
   NASA payload performance monitoring
   NASA Level 0 data archiving
   NASA Level 0 data management

NASA Level 0 data distribution
NASA Level 1 data archiving
NASA Level 1 data management
NASA Level 1 data distribution
Precision orbit determination
NASA Level 1 processing
NASA Level 2 processing